Climate change and water resources in Sweden – analysis of uncertainties

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Abstract: Simulations of the impacts of climate change on water resources in Sweden are produced within the Swedish Regional Climate Modelling Programme, SWECLIM. The impact studies are based on a combination of global climate models (GCMs), a regional climate model and a hydrological runoff model. The two different GCMs used so far are the UKMO HadCM2 from the Hadley Centre and the ECHAM4/OPYC3 of the Max Planck Institute for Meteorology. The regional climate model, RCA, was developed at the Rossby Centre of the Swedish Meteorological and Hydrological Institute (SMHI) and is a modified version of the international HIRLAM meteorological forecast model. The RCA model performs downscaling from GCM scenarios on a time horizon of 50 to 100 years. Based on the RCA scenarios, water resources scenarios were produced with the HBV hydrological runoff model developed at the SMHI. Two different methods for estimation of evapotranspiration in the hydrological model were used. Neither of the methods takes into account the possible feedback from changing land-use, vegetation dynamics or changing plant use of water at increasing CO₂ concentrations in the atmosphere. The impacts on water resources were simulated from differences between control runs and scenario runs of the RCA model for a number of selected test basins covering the major climate regions in Sweden. Changes in runoff totals, runoff regimes and extreme values were analysed with focus on the uncertainties introduced by the choice of global climate model, routines for estimation of evapotranspiration in the hydrological model and methods applied in the interface between the models. It was further analysed how these choices affect the statistical return periods of future extremes in a design situation.
1. **INTRODUCTION**

The Swedish Regional Climate Modelling Programme (SWECLIM) produces Nordic regional climate scenarios on a time horizon of 50 to 100 years in the future. In the programme are included studies of the impact of climate change on water resources in the region. Earlier water resources scenarios within SWECLIM for basins in Sweden are described by Bergström et al. (2000) and Bergström et al. (2001). Studies for Swedish basins have so far mainly addressed issues related to hydropower production, dam safety and flooding. Graham (2000) and Graham et al. (2001b) describe the hydrological impact of SWECLIM scenarios on the entire Baltic Sea drainage basin. Other regional impact studies for the Nordic countries have previously been reported by Vehviläinen and Lohvansuu (1991), Roos (1996), Vehviläinen and Huttunen (1997), Saelthun et al. (1998), Lemmelä and Helenius (1998) and Saelthun et al. (1999).

This paper gives a detailed description of the methods used for the hydrological impact studies within SWECLIM. Results are presented from the full ensemble of water resources scenarios for Swedish basins that has so far been performed within SWECLIM. The paper includes results from the latest high-resolution water resources scenarios and the analysis focuses on different sources of uncertainty that are associated with the impact study.

2. **METHODS**

Studies of the impacts of climate change on water resources are produced within SWECLIM by the use of a combination of global climate models (GCMs), a regional climate model and a hydrological runoff model. The regional climate model performs dynamical downscaling of GCM output to produce climate scenarios on a regional scale. The regional modelling makes it possible to obtain higher spatial resolution and to provide more accuracy for certain processes. Of particular importance for the Nordic region is that the treatment of the Scandinavian mountains and regional water bodies, such as the Baltic Sea and the numerous Nordic lakes, can be included in the regional climate model.

For studying the climate change impact on water resources the scenarios furthermore have to be interpreted by a hydrological model as the regional climate models at present lack, among others, detailed representation of snow in mountainous areas and river routing functions. A commonly used strategy in the hydrological modelling of climate change effects is to transfer changes of meteorological variables in the climate model to off-line hydrological simulations (Arnell, 1999; Kaczmarek et al., 1996; Lemmelä